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THE WATER RESOURCES OF COLORADO

(A Preliminary Report)

By

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Rocky Mountain Forest and Range Experiment Station

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WATER RESOURCES ARE VALUABLE

With the possible exception of soil, Colorado's most valuable natural resource is water. Because there are permanent rivers and streams it has been possible to develop irrigated agriculture, to locate and sustain industrial and community centers, to generate abundant hydro-electric power and to attract multitudes of pleasure seekers to unsurpassed natural scenic playgrounds. As a consequence a thriving State has been carved from a portion of what once was called "The Great American Desert".

Of the many uses of water, irrigation of farm crops is the most important. For example, by virtue of extensive irrigation development Colorado has taken first rank among all states in sugar beet production. In 1933 water applied to the sugar beet fields made it possible to produce a crop valued at $13,140,000--almost twice as much as the combined value ($7,876,122) of all the gold, silver, lead, copper, and zinc mined in the State during the same year. Colorado's chief source of wealth is often thought to be minerals but by liberal use of water on fertile but arid land the income from agriculture has in recent years surpassed that received from mining both metals and non-metals combined.[3/] Moreover, in contrast to the non-renewable minerals the soil and water resources, if managed properly, will produce a permanent and sustained income.

1/ Because of lack of basic data on the water resources of Colorado this report must be considered as preliminary and subject to revision as rapidly as new data become available. Lack of information also means that this statement is not all-inclusive but requires constant addition of the results of new surveys and observations. This brochure was prepared for inclusion in a general report on the agricultural resources of Colorado, thus accounting for the emphasis on the interdependency of water and agriculture.

2/ Maintained by the U. S. Forest Service at Fort Collins, Colorado, in cooperation with the Colorado State College of Agriculture and Mechanic Arts.

3/ Value of crops, mineral production, and comparison of income from agriculture and mining secured from Colorado Year Book 1935-1936, Colorado State Planning Commission, 407 p., 1937.

KIND, AMOUNT, AND ORIGIN OF WATER

The water resources can be classified conveniently under three headings: surface, ground, and seepage water. Surface water is made up largely of the flow of rivers and streams arising from natural sources. Ground water is the water beneath the surface of the soil and within the zone of saturation, and seepage water is a man-made class of water derived from the return flow of unused irrigation water to rivers and streams.

Of these various classes of water resources, surface water is by far the most important. It is estimated that 17,500,000 acre feet of surface water (streamflow) are produced in Colorado annually. Of this approximately 70 percent or 12,000,000 acre feet are produced on the western slope of the Rocky Mountains (Colorado River basin) and the remainder is produced in the basins of the South Platte, Rio Grande, Arkansas, North Platte, and Republican Rivers in the order named.4/

Ground water is of importance only in a few localities. In the San Luis Valley, for example, artesian and pumped wells provide a large share of the irrigation water to an important farming district. In the South Platte River valley pumped wells have been used quite extensively for irrigation. In 1930 there were 621 flowing and 654 pumped wells used for irrigation in the entire State.5/ It is believed that future exploration of ground water may result in vastly greater utilization of this resource, particularly for domestic and livestock water in the eastern plains region.

Seepage or return flow is of importance chiefly in lower irrigated valleys of the Platte and Arkansas Rivers. This type of streamflow has been created entirely since irrigated agriculture began and has had a very beneficial effect on the industry. Originally, rivers passed through the plains region without spreading over any great area of land. Man came and with ditches and canals began to divert water to farm lands. All the water diverted for irrigation was not consumed by plants or evaporated and the unconsumed portion percolated into the soil. The soil gradually became charged from this new source of water and new springs and seeps began to appear. Water from these springs and seeps reached rivers and streams and became available for irrigation a second time, and so on, the water being used again and again until completely consumed. Seepage flow thus created has done much

4/ Reports and Recommendations Affecting Colorado's Agriculture - Prepared by members of special committee authorized by Agricultural Clearing Committee. p. 19, 1937. (Mimeographed by Extension Service, Colo. State Agricultural College)

5/ Colorado Year Book 1935-1936. Colorado State Planning Commission. p. 73, 1937.

toward stabilizing streamflow and extending agriculture into areas which would not have sufficient irrigation water if natural streamflow was the only source of supply. Detailed studies have been made of return flow by R. L. Parshall and he estimates that the annual return flow in the Platte River valley from Kersey to Julesburg alone is worth $2,500,000 to the local farmers.6/

Colorado's water supply is strictly a home product. Rivers leave the State in every direction yet no river with a usable supply of water enters the State. The North Platte River flows northward into Wyoming; the South Platte, Arkansas, and Republican Rivers flow eastward into Nebraska and Kansas; the Rio Grande flows southward into New Mexico; and the Colorado River flows westward into Utah (Figure 1).

These rivers have their source for the most part in the high altitude, mountainous regions along the Continental Divide which constitutes the rooftree of the nation and which traverses the full length of Colorado from north to south. (Approximately 75 percent of the area of the United States lying at elevations above 10,000 feet is located in Colorado.) Each year a blanket of snow accumulates on these watersheds for from five to six months. With the approach of summer this blanket begins to disappear, streamflow increases, storage reservoirs fill and ground water in mountain valleys and slopes is replenished so that streams can be fed by springs throughout the heat and drought of the summer season. The presence of the high mountain watersheds from which these permanent life-giving rivers issue forth to parched valley lands is the salvation of irrigated agriculture. It is estimated that owing to this mountain-valley relationship approximately 80 percent of the usable streamflow is produced on only about 25 percent of the total land area of the State.

In the northeastern portion of Colorado the distribution of the precipitation tends to minimize the importance of the mountain-valley relationship because summer rainfall provides sufficient moisture to make successful dry land farming possible. Even in this locality, however, agriculture is much more stable and crops more profitable where irrigation water is available to supplement natural rainfall. The northeastern belt of rather high summer rainfall is shown in Figure 2. This map on which zones of equal precipitation are plotted also brings out that the localities having the greatest precipitation are those in the mountainous central part of the State.

6/ Return of Seepage Water to the Lower South Platte River in Colorado. R. L. Parshall, Colorado Agricultural College Bul. 279. 72 p. 1922.

IMPORTANCE OF WATER TO AGRICULTURE

Water and stabilized agriculture in Colorado are inseparable. In certain areas, depending on the rainfall, dry land farming has proven profitable but the real heart of productive agriculture is the irrigated farm land.

First to recognize the possibilities of producing farm crops under irrigation in Colorado were the American Indians. History is not exact in chronicling their activities but permanent centers of ancient civilization typified by the Mesa Verde cliff dwellings have supplied abundant evidence that irrigated agriculture was well developed. The first white men to settle in Colorado were Spaniards who pushed their civilization into the Rio Grande and Arkansas River basins and sustained their outposts with crops produced by irrigation. Farming developed slowly under the Spanish regime, however, and not until discovery of gold in 1858 brought a wave of settlers into northern Colorado was crop production placed on a commercial basis.

Farm lands to provide food for the miners were cultivated first in the vicinity of Denver and Golden in the late 1850's though the first permanent white settler to engage in agriculture in northern Colorado had located on the Cache la Poudre River more than a decade before.7/ As soon as irrigated agriculture got under way it increased at an amazing rate and by 1864 Federal reclamation projects were being urged. In 1873 President Grant included in his message to the Congress a proposal for irrigating farm land on the eastern slope of the Rocky Mountains. In 1876 F. V. Hayden estimated the tillable land in Colorado at 4,686,720 acres and pointed out the necessity for irrigation. Hayden's report also included a statement describing the active Greeley irrigation development which was the first practical cooperative irrigation enterprise in the State.

By 1882 the Cache la Poudre Valley was described as "one vast network of irrigating canals" and other areas were equally as well developed. In 1888 Elwood Mead estimated that 1,250,000 acres were under irrigation in Colorado. Also in 1888 the historic State Supreme Court decision was handed down which declared ditch companies common carriers without property interest in the water and hence these companies could charge no royalties and exact only reasonable fees for carrying and delivering water. This decision served to place irrigation in Colorado on a safe and sound basis without uncertainty as to future cost of water.

The decade 1880 to 1890 saw the most rapid development of irrigation enterprises in the State, and although sound planning was not followed in every respect permanent irrigation districts grew and pros-

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7/ History of irrigation from an excellent discussion in "History of Agriculture in Colorado" A. T. Steinel. Published by the State Board of Agriculture, pp. 167-244.. 19 26.

pered. By 1899 Colorado had become the first ranking State in the Union in acres irrigated and held this rank until 1919 when California forged ahead following an extended ground water development program. Colorado still ranks first of all States in area of land irrigated directly from streams.

Latest census figures show that 3,393,000 acres valued at $309,265,000 were being irrigated in 1930. Approximately 52 percent of all farms in the State are irrigated wholly or in part and $87,603,000 has been spent on irrigation improvements.[8] Of the 4,700,000 acre feet of water consumed annually within the boundaries of the State more than 90 percent is used for crop production, the remainder being used for domestic and industrial purposes.[9] The value of the water used for irrigation in terms of rural and urban income is indeterminate though G. S. Klemmedson has estimated that $1,000,000 worth of water in northern Colorado will produce crops valued at from $13,000,000 to $44,000,000 depending upon the kind of crop.[10]

Because of the location of arable land in Colorado three-fourths of the acreage irrigated at present is on the eastern slope of the Rocky Mountains whereas only 30 percent of the total surface water is produced on watersheds tributary to this land.[9] The remaining one-fourth of the irrigated land is located on the western slope of the Rocky Mountains with tributary watersheds which produce 70 percent of the State's total surface water supply. This unequal distribution of land and water resources results in complete utilization of the eastern slope waters but an excess of nearly 10,000,000 acre feet per year on the western slope.

Before the limitations of the available water on the eastern slope were recognized irrigated agriculture expanded during years of favorable rainfall to a point where the average annual supply of water at present is not sufficient to meet the demand. This point of overdevelopment was reached about 20 years ago almost simultaneously with the cessation of expansion of irrigation on the western slope owing to lack of arable land which could be watered economically. With the expansion of agriculture arrested, population and industrial increases have been retarded similarly until at present the future of Colorado depends more on water development than on anything else.

8/ Colorado Year Book 1935-1936. Colorado State Planning Commission, p. 407, 1937.

9/ Report and Recommendations Affecting Colorado's Agriculture, prepared by members of Special Committee Authorized by Agricultural Clearing Committee, p. 19, 1937. (Mimeographed by Extension Service, Colo. State Agric. College)

10/ News article in Fort Collins Express-Courier, May 1936.

Because of over-expansion of cultivation on the eastern slope, the major water problem does not rest on reclamation of new lands but on securing additional water for established and operating irrigation districts. Two methods of securing more usable water on the eastern slope are feasible: (1) additional storage, and (2) transmountain diversion from the Colorado River. The first method already has been developed to an economic limit in the South Platte River basin and will be almost fully developed on the Arkansas River if and when the Caddoa Dam is completed. In the Rio Grande drainage some additional storage may be possible but, in the main, transmountain diversion of water is the only permanent solution with additional storage reservoirs on the western slope to compensate for the diverted water.

Of the possible transmountain diversion projects the Colorado-Big Thompson, the Blue-South Platte, the Gunnison-Arkansas and the Animas-Rio Grande diversions are the most important possibilities. Of these projects the Colorado-Big Thompson has been investigated thoroughly and pronounced feasible by the U. S. Reclamation Service. Estimates show that a $44,000,000 investment in this project ($19,000,000 of this sum is for self-supporting power plants) would provide sufficient water to prevent reoccurrence of crop losses said to have totalled approximately $42,000,000 in the 10-year period 1925 to 1934, inclusive.[11] At least 310,000 acre feet of additional water would be supplied annually to the 615,000 acres of irrigated land in the South Platte basin. This diversion would not hinder or encroach upon present or future irrigation in the Colorado River basin, provided a reservoir to compensate diversion by storage is built on the western slope. Other diversions may be equally as feasible as the Colorado-Big Thompson but they either have not been or are still in the process of being investigated.

Surveys are in progress also to determine the feasibility of additional irrigation projects in the Colorado River basin. There is little doubt that by use of storage dams and other improvements additional land can be brought under cultivation in this basin but widespread and apparently well-founded opinion indicates that there is insufficient arable land to utilize all the tributary water.

Various estimates have placed the total arable land acreage in Colorado susceptible to irrigation at between 4,500,000 and 5,000,000 acres.[12] To fulfill these estimates would mean reclaiming approximately 1,500,000 acres unirrigated at present. Only careful surveys designed to determine all aspects of land and water relationships will determine whether or not a reclamation program of this magnitude is feasible.

11/ News article Summarizing Report of U. S. Bureau of Reclamation. Fort Collins Express-Courier. February 21, 1937.

12/ History of Agriculture, A. T. Steinel. Published by the Colorado State Board of Agriculture, pp. 164-244, 1926.

USABILITY OF WATER DEPENDS ON THE WATERSHED

The character of the flow of every stream is influenced greatly by its watershed. Climate, of course, exercises the basic control over streamflow but the soil (geology), topography, and vegetation of the watershed dictate whether or not run-off will be rapid or delayed and whether or not erosion will be serious or negligible. Of these four major factors influencing streamflow only the vegetation is subject to control by man. As a result, the practical significance of the watershed in a general discussion of water resources revolves around this one factor that can be moulded according to man's wishes.

One of the major influences of vegetation on the utility of streamflow can be observed where serious acceleration of erosion has been brought about by abusive use of the plant cover. Numerous examples are available in Colorado illustrating that misuse of vegetation has resulted in a vast network of gullies in what was originally an uneroded, well stabilized watershed. Clear streams flowing swiftly over boulder-strewn beds were produced from those virgin watersheds but the present streams from eroded areas are silt-laden and meander sluggishly along beds choked with sand and mud. The new raw gullies are draining and reducing ground water, irrigation and other improvements are being clogged by the silt-laden streams and less water in general is available for productive use. All of these changes are traceable directly to unwise management of the vegetation and man's failure to realize the important influence of plant cover on the yield of usable water.

In addition to causing accelerated erosion, misuse of the vegetation sets the stage for accelerated run-off. When the plantcover is removed the absorptive capacity of the soil decreases and no physical obstructions are present to break the fall or the flow of the storm water. Water collects quickly, forms into rivulets and soon has gathered sufficient head to flow down the slopes and in ravines with ever-increasing velocity. Under these conditions floods increase in frequency and severity and there is a tendency for streams to run bank full or overflow during storm periods or snow-melting seasons and to be reduced to a mere trickle or dry up completely during drought periods. Poorly regulated streamflow, which is inevitable if watersheds are misused and water does not enter the soil to appear later as springs and seeps, means that a minimum of water will be available for productive use and that water shortages during drought periods may become acutely aggravated. It is entirely possible that unprecedented shortages of irrigation water will result even in favorable climatic years if tributary watersheds are continuously mal-treated.

With proper management of watershed lands and regulated use of the vegetation accelerated erosion and run-off does not occur. Plants are present to bind and stabilize the soil, water can readily penetrate the surface mantle and total usable water yields from well managed areas may even be increased over and above the yields from similar virgin or totally protected areas. To stabilize soil and insure acceptable water yields systems of land management must be evolved with watershed conservation fully in mind. If the watershed is grazed the range should be utilized only to the point where destructive erosion and run-off will not result and if the watershed supports a forest the timber must be harvested under carefully planned regulations which will permit maximum yields of usable streamflow.

This relation which exists between watershed conditions and the quality and quantity of streamflow makes it imperative that the land producing the water and the water itself be considered as a single entity. The irrigationist in the lowland valley or plain who is vitally interested in the water in the ditch at his back door should be equally as concerned about watershed conditions in the bordering mountains from which this water comes. And the man who is using the mountain watershed should be responsible for handling his lands in a way that will not impair the water supplies of the irrigationist in the lowland valleys.

RESPONSIBILITY FOR REGULATION OF WATER AND WATERSHEDS

Utilization of surface water has always been under direction and regulation of the State government. Colorado early recognized the importance of regulated use of water and perfected a code of workable water laws which have served as a guide for other states facing a similar task. This code provides essentially that established and beneficial use of a given quantity of water properly adjudicated constitutes an inviolable right of appropriation. Priority of appropriation is based on seniority of established rights and duration of rights depends largely on whether or not beneficial use of the water is made. This legislation has proven very satisfactory.

Regulated use of watersheds, on the other hand, has not followed such definite procedure and management of important water yielding areas with water production in mind has been neglected except by the Federal Government with the U. S. Forest Service taking the lead. On the 13,543,000 acres of national forest land in Colorado, including most of the important watershed areas, a system of regulated use planned to protect watershed values has been practiced for more than 30 years.

A few mistakes resulting in impairment of watershed utility have occurred on the national forests but, as a whole, utilization of the various resources has not damaged the water yield. It is not generally recognized that the national forests while comprising only a little more than 20 percent of the total area of the State produce from two-thirds to three-fourths of the usable streamflow. In view of the dependency of the welfare of the State on the watersheds of the national forests the U. S. Forest Service is making every effort to investigate attendant problems and evolve a scientific basis of watershed management.

Recently the Soil Conservation Service has become active in erosion control and run-off retardation on agricultural lands and is pointing the way toward more satisfactory utilization on this class of property. With the exception of the demonstration work of the Soil Conservation Service, little has been done toward regulation of private and State owned land on important watershed areas. Some individuals, recognizing the need for conservative management, have imposed self-regulation on their lands with considerable success and economic return but many have not been in a position or are without inclination to do other than exploit their land for the greatest and most immediate financial return.

In general, watershed management and regulation on a large scale is beyond the realm of private responsibility. No man should be judged too harshly for following some practice that unwittingly damages the water supply of some stranger a hundred miles or more distant. Nor perhaps should the State government be held directly responsible for regulated use of watersheds because rivers cross state lines and the office worker in Los Angeles may be as dependent on the Colorado River as the irrigationist at Grand Junction. Watershed regulation is really a national problem and logically should be the responsibility of the Federal Government though the State can aid greatly with helpful and specific legislation and private individuals can be of real assistance by handling their lands properly.

Regardless of who or what agency takes the lead in watershed management and regulation there must be unity of action. The Forest Service, Soil Conservation Service, National Park Service, Indian Service, Division of Grazing, State Board of Land Commissioners, State Agricultural College, State Planning Commission and other public and private agencies must coordinate their activities and interests to perfect a well rounded program of watershed regulation. In streamflow regulation and improvement the State, Geological Survey, Reclamation Service, and Army Engineers must pool their forces and work toward a common end that assures maximum utilization of waters and flood prevention. To secure coordinated action a water conservation commission maintained as an integral part of the State government would be extremely helpful.

WATER PROBLEMS REQUIRING ATTENTION

In the rush to utilize readily obtainable water and secure immediate and maximum economic returns a definite plan for using and preserving the water resources of Colorado has been forgotten. This neglect has resulted in misfortunes but there is still much to be gained by preparation of a plan now.

At present many data needed to develop a complete and finished program are lacking but sufficient information is at hand to make a significant start. One of the first steps should be to ascertain where the gaps in existing knowledge are and how they can be filled. For example, new stream gauging stations for water inventory purposes are needed; additional climatic records, particularly at high altitudes, must be obtained; snow surveying and streamflow forecasts should be extended; the location and extent of arable lands susceptible to irrigation should be ascertained and water rights for future use secured insofar as possible; the engineering and economic aspects of trans-mountain diversions and other possibilities for securing additional irrigation water where needed must be investigated; flood hazard surveys must be made; legislation to facilitate regulated use of watersheds must be written; silt loads of rivers and silt disposal in irrigation improvements must be investigated; expansion of studies dealing with watershed management is needed; and ground water resources should be investigated. Not until most, if not all, of the above needs are met will Colorado be on an even footing with the progress being made in the utilization of the water resources in other progressive western states.

Some farsighted actions such as the Colorado River compact and the protection of the watersheds on the national forests are outstanding exceptions to the passive attitude Colorado has taken toward its water resources. Such an attitude should exist no longer, or Colorado --"the rooftree of the nation"--will be supplying water to neighboring states at serious expense to itself.

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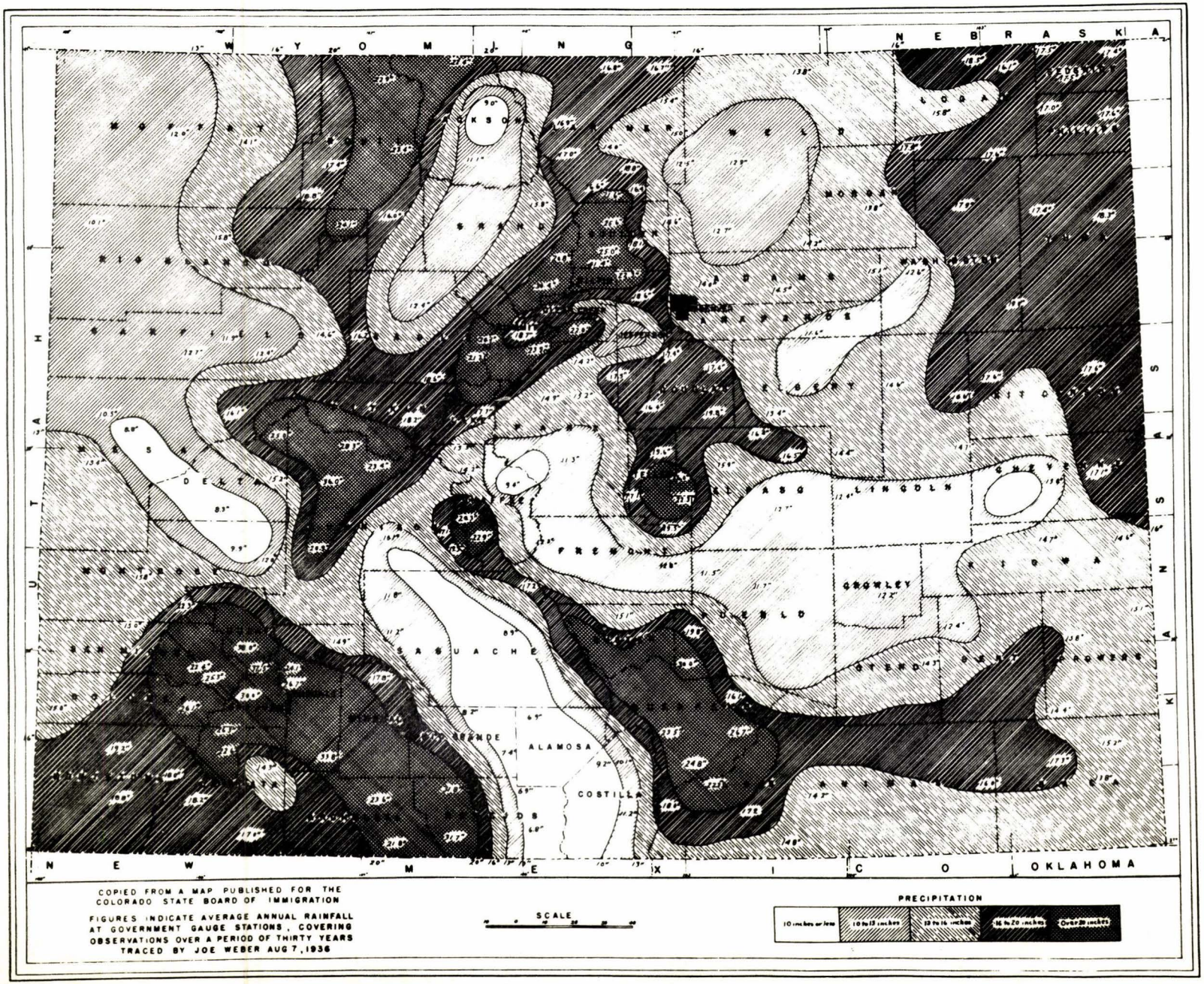
Figure 1: MAJOR DRAINAGE BASINS OF COLORADO

RIVERS LEAVE COLORADO IN EVERY DIRECTION BUT NO MAJOR, USABLE STREAM ENTERS THE STATE

FIGURE 2:- **RAINFALL AREAS IN COLORADO**



COPIED FROM A MAP PUBLISHED FOR THE COLORADO STATE BOARD OF IMMIGRATION

FIGURES INDICATE AVERAGE ANNUAL RAINFALL AT GOVERNMENT GAUGE STATIONS, COVERING OBSERVATIONS OVER A PERIOD OF THIRTY YEARS TRACED BY JOE WEBER AUG 7, 1936